On the Formation of Photographic Star-Discs.
By H. F. Newall, M.A.

It is probably generally admitted that the formation of photographic star-discs is not yet understood. A telescope which ought theoretically to give a spurious disc, whose diameter is, let us say, 1″, gives in practice a photographic disc whose diameter increases with the brightness of the star and the exposure given to the plate, and may reach a value approaching or even exceeding 60″—a statement which is true not only of refractors but also of reflectors. This is a defect, and a very serious defect for some investigations; on the other hand, in some cases it is a positive advantage, and astronomers make the best of the peculiarity by basing estimations of star magnitudes upon it. It is difficult to form an idea as to how much labour and trouble in such an undertaking as the making of the Photographic Chart is saved by the existence of these expanding photographic discs. One may almost say that it has now come to be a distinct merit in an instrument that it should give expanding discs.

In applying photography to the determination of parallax it would clearly be an advantage to get more point-like images both of bright stars and of faint stars with a given exposure. Hence it would appear to be of considerable importance to advance, if possible, to a knowledge of the secret of the formation of expanding photographic discs, and I beg leave to lay before the Society an account of some experiments and measurements bearing on the subject.

The importance of a vigorous attack on the subject is obvious, inasmuch as there are many proposals to build large photographic telescopes. Let me instance the 18-inch photographic telescope suggested for the Cambridge Observatory, and the 26-inch photographic telescope for Greenwich. It is not quite clear that from such telescopes results may be expected proportionate to the dimensions and cost of such instruments, unless some departure is made from the existing mode of construction of the object-glass. A larger scale in the photograph, in which everything is equally magnified, not only separation of star-centres, but also disc diameters, would not bring much advantage.

One of the most notable points about a good photographic star-image is the definiteness of the boundary of the disc, whatever its diameter may be. In the case of a prolonged exposure the image of a bright star may readily come to have a diameter exceeding 1 millimetre on the photographic plate. Yet the distance (measured along the radius) in which the density of silver deposit changes from full value to zero is a very small fraction of the radius of the disc.

Scheiner has recently published an important paper, "Ueber

die Verbreitung der photographischen Sternscheibchen" (*Ast. Nach.* No. 3173, vol. cxxxiii. 1893, p. 73). He calls attention to the experiments made by Dr. Max Wolf, by which it has been proved that the growth of the photographic star-disc in long exposures cannot be attributed solely to diffusion of light within the sensitive film from the bright star-image formed on the film during the exposure.

In Wolf's experiments the sensitive plate was in part covered by an opaque meshwork, and was in this state exposed in the telescope to a region rich in stars; some star-images fell on uncovered film, others on the opaque bars, others on the edge of the bar, and it was seen that the extension of the discs occurred whether the central brightest part of the star-image fell on the bar or on the uncovered film. Dr. Wolf was good enough to show me the images two years ago, when I was in Heidelberg, and my recollection of the appearances may be conveyed by the figures given on Plate 10, fig. 1.

A second experiment of Dr. Wolf's consisted in brushing dust over a plate before it was exposed. After development it was clear that where a star-image had fallen on a particle of dust a shadow was cast, even though such shadow was close to the boundary of the disc. This shadow could only have been cast by light emanating from the object-glass.

Both experiments prove that the expansion of the disc is in the main due to the impact of light coming from the object-glass. Dr. Scheiner has made further experiments which prove that there is *some* extension due to radial diffusion of light within the film from the centre of the image, but that this extension is always relatively small.

In investigating the performance in photographic work of a large visual telescope, some account of which I had the honour of communicating to the Society at the last April meeting, I came across phenomena in the star-image which were obtained on various plates, and as they seem to throw light on the question, I proceed to describe them.

An enlargement of the mark made by α *Lyræ* on an ordinary photographic plate placed near the visual focus of the 25-inch visual refractor at Cambridge is shown in fig. 2 of Plate 10. The series of rings which are seen in this mark have been investigated with interesting results. The mark may be described as a circular spectrum whose red end is at the centre, and whose violet end fades into invisibility at the confines of the mark. The rings are the hydrogen absorption lines in this circular spectrum of α *Lyræ*.

The plate, when placed at the visual focus, is $31^{\text{mm}}\cdot 2$ from the focus for H_δ light. Had the star emitted only H_δ light, the circle of diffusion on the plate would have had a diameter of $2^{\text{mm}}\cdot 2$, and the light would not have been equally diffused over this circular mark; but for reasons not yet fully understood, the brightest part would be the outer annulus. The general effect would be similar to that shown in fig. 3, Plate 10. If the

exposure were so short that only the brightest part of the mark were impressed on the plate, there would be simply a bright ring about $2^{mm}\cdot 2$ in diameter, and darkness within and without the ring.

If, on the other hand, the star emitted all kinds of light except H_δ light, and if light of each particular wave-length were collected into an annulus whose diameter was appropriate to the distance of the plate from the focus for the light of the wave-length considered, there would be contiguous bright annuli giving the appearance of regular illumination all over the mark with the exception of one dark annulus for the absent H_δ light.

The concentration of light into the outer ring of the diffraction pattern in any circle of diffusion is a well-known phenomenon, and excessive concentration is taken to be a proof of the existence of outstanding spherical aberration. I return to this point later (see page 522).

Marks similar to that illustrated in fig. 2 were obtained at various focus readings of the photographic plate, and careful measurements were made of the several rings in each mark. The measurements show that as the plate is moved uniformly outwards from the visual focus the rings contract uniformly. We may, in fact, regard each ring as the section of a right circular cone whose axis is the axis of the cone of rays from the object-glass: each ring has its own cone, its apex lying on the axis and being coincident with the focus for light of the wave-length corresponding with the marked absorption lines in the spectrum of the star. Stars of different spectral type give marks showing different rings. I deal with this point in a separate paragraph (see page 521).

I give in the following lines the results of measurements of the rings at different focus readings, taken from a plate exposed 1893 November 13, 6·30; *a Lyræ.* Three rings were measured in each mark.

df. Focus reading of plate from arbitrary zero near visual focus.	Inner Ring. D. Measured diameter of ring.	D × 14·0.* Deduced distance of apex from plate.	(D × 14·0) + df. Deduced distance of apex from zero of focus readings.	Middle Ring. D.	D × 14·0.	(D × 14·0) + df.	Outer Ring. D.	D × 14·0.	(D × 14·0) + df.
mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
0·0	2·62	36·7	36·7	3·42	47·9	47·9	4·10	57·4	57·4
2·4	2·38	33·3	35·7	3·22	45·1	47·5	3·96	55·4	57·8
4·8	2·10	29·4	34·2†	2·94	41·2	46·0†	3·64	51·0	55·8†
7·2	2·04	28·6	35·8	2·82	39·5	46·7	3·66	51·2	58·4
9·6	1·94	27·2	36·8	2·74	38·4	48·0	3·40	47·6	57·2
12·0	1·74	24·4	36·4	2·60	36·4	48·4	3·22	45·1	57·1
14·4	1·54	22·1	36·6	2·40	36·6	48·0	2·98	41·7	56·1
16·8	(ring too faint to measure)			2·20	30·8	47·6	2·82	39·5	56·2
		Mean	36·0		Mean	47·5		Mean	57·0
			5·2			5·2			5·2
			30·8			42·3			51·8
			31·2			42·1			51·6

* The ratio focal length : aperture is 14·0.

† Something peculiar about readings in this third mark; no reason can be given to warrant the rejection of them.

The mean of the deduced distances of the apex from the plate is given for each ring, and the smallness of the deviation from the mean in each column shows that the conclusion I reach is justifiable, namely, that each ring is the section of a conical shell in which there is little or no light.

The plate from which the above measurements were made was taken for a different purpose, and the actual position of the arbitrary zero from which the focus readings were measured was not recorded; but reasons given in a later paragraph (see page 522) lead me to ascribe the inner ring to the H_δ focus, the middle ring to the H_ϵ focus, and the outer ring to the K focus, each of these focuses being dark in consequence of the absorption of the light in the star's atmosphere.

If the visual focus were at $5^{mm}\cdot2$ from the arbitrary zero,* we should get the apex for the

	mm.	
inner ring at	30·8	from the visual focus
middle „	42·3	„ „
outer „	51·8	„ „

Now the distance of the

H_δ focus from the visual focus is	31·2	See *Monthly Notices*, present volume, page 373.
H_ϵ „ „ „	42·1	
K „ „ „	51·6	

For ease in comparison these numbers are put together below the "means" in the table given on the preceding page.

On another plate (1893 December 7, 6·30; *α Lyræ*, 10 minutes' exposure) which was exposed specially with a view to bring out, if possible, more rings, five rings were measured with the following results:

	Measured Diameter mm.	Distance of Apex from plate $=D\times14\cdot0$. mm.	Distance of Apex from assumed visual focus $=(D\times14\cdot0)-7\cdot6$.	Distance of focus for hydrogen lines from visual focus.
Innermost ring	1·64	22·96	15·36	H_γ 15·4
Inner ring	2·78	38·92	31·32	H_δ 31·2
Middle ring	3·64	50·96	43·26	H_ϵ 42·1
Outer ring	4·24	59·36	51·66	K 51·6
Outermost ring	4·68	65·52	57·92	H_ζ 61·2

The focus reading for this plate was, $2^{mm}\cdot4$, and if we again assume that $5^{mm}\cdot2$ is the position of the visual focus, then the distance of the apex of the cone, whose section is a ring, from the visual focus is less by $7^{mm}\cdot6$ than the number given in the

* In determining the diameter of a ring, the wire of the micrometer was set tangential to the *middle* of the annular dark ring at each end of a diameter. Hence, the deduced diameter is not exactly that of the circle of diffusion regarded from the standpoint of geometrical optics. The correction $5^{mm}\cdot2$ contains a correction for this.

column D × 14·0. These diminished distances should agree with the distances of the various hydrogen focuses from the visual focus if my hypothesis is correct. A comparison of the last two columns shows how far this is the case. I should add that the outermost ring was very difficult to measure, being extremely faint.

When a spectrum is photographed on an isochromatic plate, such as Edwards's, two maxima of photographic action are obvious —one in the yellow green, the other not far from the H_γ line—and further an obvious minimum is seen between the *b* lines and the H_β line : the plate is only slightly sensitive to the blue green. This insensitiveness to the blue green produces the same effect, so far as photographic action is concerned, as if the plate were as highly sensitive to the blue green as to other parts of the spectrum, and blue-green light were not allowed to fall on the plate.

If such a plate is set at some distance outside the visual focus of the telescope, and is exposed to the light of a star, such as *Procyon*, the mark produced on the plate has the appearance shown in fig. 4, Plate 10.

The outer bright ring is the annulus due to the yellow-green light, to which the plate is highly sensitive.

Just within this bright ring is a dark annulus due to the insensitiveness of the plate to blue-green light, and this is an effect which might be brought about on a uniformly sensitive plate by a star with a dark absorption line in the blue green.

Within the dark ring is a bright disc attributable to the superposed circles of diffusion due to blue and violet light.

Lastly, the central nucleus is mainly due to that light which is brought to a true focus on the plate.

The only way in which the mark produced by the same star on an ordinary plate (such as Wratten & Wainwright's) set at the same distance outside the visual focus differs from that produced on the isochromatic plate consists in the absence of the outer bright annulus. This in itself is strong evidence that the bright annulus is due to yellow-green light.

A series of marks has been got on an isochromatic plate set at various focus readings. Measurements were made of the diameter of the bright annulus, and it was found that the diameter of the bright annulus in any mark bore a constant ratio to the distance between the plate from the visual focus when that mark was produced. The bright annulus is, in fact, the section of a right circular cone whose apex is at the visual focus. Similarly, it was shown that the dark annulus is the section of a right circular cone whose apex falls between the visual focus and the focus for H_β light. It is not necessary here to give in full the measurements by which these facts were established. They were more precise than those given for the rings due to hydrogen absorption in *α Lyræ*, inasmuch as the visual focus was made the arbitrary zero for the focus readings of the plate. See fig. 5, Plate 10.

When the isochromatic plate is moved inside the visual focus, *i.e.*, nearer to the object-glass, it may be seen under certain circumstances that the bright annulus due to the yellow-green light is surrounded by a dark annulus due to the blue green; and that is to say, that, outside the visual focus, the bright annulus due to yellow-green light is outside the dark annulus due to the blue-green light, whereas inside the visual focus the dark annulus is outside the bright one.

A figure affords the readiest way of realising how this change takes place. See fig. 6, Plate 10.

In one mark which I have got on an isochromatic plate set $1\frac{1}{2}$ inch inside the visual focus, the bright and dark annuli due to these peculiarities in the sensitiveness of the plate are seen surrounded by the dark rings due to many of the absorption lines of hydrogen in the star *Procyon* which made the mark; it is possible to trace the rings due to H_β, H_γ, H_δ, and H_ϵ with certainty, and those due to K and H_ζ with some difficulty. See fig. 9, notably, *d*, *e*, *f*.

Fig. 7 shows on an enlarged scale the marks made by *Procyon* on an isochromatic plate exposed behind a dark yellow glass at various focus readings, the exposure being four minutes in each case.

a	*b*	*c*	*d*	*e*
$-1\frac{1}{2}$ in.	$-\frac{3}{4}$ in.	0	$+\frac{3}{4}$ in.	$+1\frac{1}{2}$ in.

The diameters of the bright annulus which I ascribe to the yellow light are

$2^{mm}\cdot54$	$1^{mm}\cdot36$	$^{mm}\cdot31$	$1^{mm}\cdot42$	$2^{mm}\cdot74$

I will not dwell on the difference between the measured diameters on the two sides, as I am not prepared to say that the middle exposure was made precisely at the visual focus.

But I hasten to point out that the bright centre in the marks outside the visual focus are due to the blue and violet light which, when condensed as it is on the plate placed in the midst of the focuses for these colours, is able to pass through the yellow glass in large enough quantities to affect the plate. I have exposed an ordinary (not isochromatic) plate (of about the same sensitiveness in the blue and violet as the isochromatic plate) behind the same dark yellow screen as was used in taking the marks figured above, and have found that enough blue and violet light gets through the screen to make marks as strong as the centres of the marks figured above, and measurement shows that the dimensions of the inner disc and nucleus are the same in the two cases.

Influence of the Spectroscopic Nature of a Star's Light on the appearance of the Rings in the Marks made by the Star.

The rings are not equally noticeable in the marks made on the plate by different stars.

In the mark of *α Cygni*, there is hardly a trace of a ring

The lines in the spectrum of this star are narrow, as is well known. The mark of *α Lyræ*, taken on the same plate on the same night, shows well-defined rings.

In the mark of *α Aurigæ*, two rings are marked. There are two broad absorption lines in the spectrum of this star, namely, H_ϵ and K. Measurement of the rings proves that the rings have diameters which coincide with those of the circles of aberration for light coming from the focuses of H_ϵ and K.

In the marks of *α Canis Majoris* and *β Tauri*, the set of rings seen are similar to those seen in *α Lyræ*. The hydrogen lines are marked in all these stars.

In the marks of *α Boötis*, traces of H_ϵ and K rings are seen only after considerably longer exposures than are needed to show them in *α Lyræ*. The marks of *α Lyræ* and *α Boötis* have been taken on one plate side by side, exposures of $\frac{1}{2}^m$, 2^m, 4^m, and 8^m being given to each star. Rings are visible in all the marks of *α Lyræ*, additional rings being added on the outer boundary with the longer exposures, but only the eight minutes' exposure for *α Boötis* shows the H_ϵ and K rings distinctly, the boundary being well defined in all exposures after the half minute, and the only effect of longer exposure being to increase the density of the image within the radius of the H_ϵ absorption ring. The well-known distribution of light in the spectra of these stars would account for the observed differences. A comparison of the diameters of the rings in *α Boötis* and *α Lyræ* leads to the identification of the rings in *α Lyræ* referred to on p. 519.

Spherical Aberration.

The whole explanation which I suggest of the peculiarities observed in the marks depends on the concentration of light in the outer part of the circle of diffusion for light of any wave-length. As it appeared that there were signs of *excessive* concentration which might be attributed to spherical aberration, I exposed a plate to one and the same star, and used different apertures.

Having found that the most marked ring was that seen on isochromatic plates, I used such a plate for this purpose, and found that the ring was equally well developed whether the aperture used was 24 inches, 18 inches, 12 inches, or 6 inches.

The plate was set at a fixed distance ($1\frac{1}{8}$ inch) outside the visual focus, and the marks produced with different apertures were obtained side by side on the plate. The rings were measured, and the proportionality of diameter of the outer ring to the aperture was confirmed.

	12-inch Aperture.	18-inch Aperture.	24-inch Aperture.
Diameter	$1^{mm}\cdot129$	$1^{mm}\cdot645$	$2^{mm}\cdot218$
	$26''\cdot3$	$38''\cdot4$	$51''\cdot7$
$\frac{\text{Diameter}}{\text{Aperture}}$	$\frac{1\cdot13}{12} = \cdot0927$	$\frac{1\cdot65}{18} = \cdot0914$	$\frac{2\cdot22}{24} = \cdot0924.$

Fig. 8 is an enlargement of the marks taken on one plate with the three larger apertures. The marks for the 12-inch and 6-inch apertures were taken on a separate plate, but the ring is somewhat difficult to print when the diameter is so small.

Distribution of Light in Circle of Diffusion for Light of given Wave-length.

In order to study the distribution of light in the circle of diffusion for light of any given wave-length resort must be had to artifices.

First, a pinhole backed by a sodium flame was set up at a distance, and was observed with a $4\frac{1}{4}$ refractor by Cooke of most excellent qualities. The concentration of light in the outer annulus of the circle of diffusion was very marked.

What is true for one telescope, however, is by no means necessarily true for another, and the above observation is recorded merely to show that a strong concentration of light in the outer annulus is present in the case of a telescope, which shows no sign of spherical aberration in the ordinary tests.

For the 25-inch refractor I have investigated the matter by putting an isochromatic plate at a focus-reading $1\frac{1}{2}$ inch within the visual focus behind a dark yellow glass. In this way I attempted to separate the effects due to yellow-green light from those due to blue and violet, for the yellow glass cuts out the blue and violet much more strongly than the yellow and green; further, the blue and violet light is very much more diffused on the plate because the focuses are more than twice as far from the plate; and, lastly, the blue and violet focuses are comparatively sparsely distributed along the axis, whilst the yellow-green focuses are condensed into a very short length of axis. Fig. 9, *a*, *b*, *c*, shows the mark obtained in this way when the plate is exposed to the action of the light coming from the star Procyon. Further, some idea of the separation of the effects of the blue and yellow lights is gained by a study of fig. 9, Plate 10 (see explanation of the figures at the end of the paper).

There seems to be established by these experiments the fact of the existence of an important concentration of light in the boundary of the circle of diffusion for light of any wave-length. As to the physical reason for this annular concentration I am not at present prepared to speak. But Lommel's work gives one grounds for thinking that it may be a straightforward result in the theory of diffraction through a circular aperture. I have not found the energy or time as yet to grapple with an extension of Lommel's work, but I hope that someone more versed in the use of Bessel's functions than I can claim to be may be induced to attack the problem. But we must admit that the annular concentration exists, whatever the cause of it may be.

Now *assume* that in the "photographic" telescope the correction of chromatic aberration is not perfect. Then we see that with

prolonged exposures the effect of the focuses remote from the plate will make itself felt in the addition of rings to the disc already formed by the nearer focuses.

In this way the well-known facts relating to the differences between visual and photographic magnitudes receive a simple explanation. A star which has a strong ultra-violet spectrum produces a disc whose diameter is quickly increased by the addition of ultra-violet rings.

The absence or faintness of light at the centre of the larger circles of diffusion suggests a simple explanation for a feature which has always surprised me—namely, that the centres are not more quickly solarised.

In order to gain some idea as to the growth of a monochromatic image on a photographic plate with increasing exposures, I have used the objective prism in front of the object-glass to throw a spectrum of *Polaris* on a Wratten & Wainwright plate. The clock was rated and the telescope guided so as to avoid any trail of the spectrum on the plate. On one plate I made four exposures—2 min., 4 min., 10 min., and 65 min.—and measurements at the same part of the spectrum in all the four exposures show that the growth in width is very small.

			mm.		″
In the	2 min.	exposure the width was	0·077	or	1·79
„	4 min.	„ „	·119	„	2·77
„	10 min.	„ „	·147	„	3·42
„	65 min.	„ „	·170	„	3·96

Atmospheric tremor produces sudden movements of a star in the field of view of the telescope, and these often amount to as much as 2″. In trails of stars across a fixed plate in a stationary telescope I have measured the deviations in declination from the straight line described by the star: this was done with a view of estimating how much of the width of these spectra of *Polaris* is attributable to similar movements on the plate. Deviations amounting to 2″ have been measured in trails taken on not very bad nights. On a night in which the seeing was described as "very good $\frac{4}{5}$," the deviation measured was 1″·5. On a night when the seeing was described as "very bad $\frac{1}{5}$," the deviation measured was 6″. The total amplitude was double these numbers; and it appears, therefore, that the movement of the image on the plate will account for a great part of the width of the spectrum.

It must be remembered, however, that in dealing with a small part of the spectrum we deal with a very small part of the light of *Polaris*, so that these four images of the spectrum should be compared with the images of very faint stars.

I may refer to the case of a star-mark which I have obtained on an isochromatic plate. The plate was so set that the ring due to the yellow-green light was larger than any that could be formed by any other light. Measurement showed that the in-

crease in diameter when the exposure was prolonged was very small. Some similar measurements are given on p. 378 of the present volume.

I do not hesitate to think that the cases of reflectors and refractors must be dealt with separately. I have been led to the view that chromatic aberration is the prime cause of expansion of photographic star discs obtained with refractors. It appears doubtful whether a perfect correction *can* be obtained with only two lenses in the object-glass. There remains the case of the reflector still to be explained.

The success of Dr. Hastings's triple objectives was so encouraging that one rejoices that Messrs. Cooke & Son have been able to secure large discs of special glass, which Mr. Taylor has found on calculation to promise excellent colour corrections, and it is to be hoped that in the attempt to produce an object-glass which will serve equally well for visual and photographic work the optician does not set on himself a constraint which will stand in the way of the best possible results in either one or the other line.

Explanation of Figures in Plate.

With the exception of figs. 1 and 6, the figures are enlargements (about two-and-a-half-fold in all cases). The figures are *negatives*. The photographic reproduction does not do justice to the admirable pencil drawings made by Mr. Wesley from the original negatives.

Fig. 1.—To illustrate Dr. M. Wolf's experiment.

a. Star image fell on the uncovered film. *b.* Centre of image fell on centre of bar. *c.* Centre of image fell on edge of bar.

Fig. 2.—Mark produced by α *Lyræ* on an ordinary plate set at the visual focus: exposure, thirty seconds. Radial marks due to diffraction. Concentric rings are those referred to in the paper.

Fig. 3.—To give an idea of the distribution of light in a circle of diffusion for light of given wave length.

Fig. 4.—Mark on an isochromatic plate set $1\frac{1}{2}$ inch outside the visual focus. Outer ring due to yellow-green light.

Fig. 5.—Set of marks on an isochromatic plate set at different focus-readings outside the visual focus: exposure, thirty seconds in each case. Procyon.

a. $\frac{9}{16}$ in. *b.* $\frac{3}{4}$ in. *c.* $\frac{15}{16}$ in. *d.* $1\frac{1}{8}$ in. *e.* $1\frac{5}{16}$ in.

Fig. 6.—To illustrate change in position of rings inside and outside the focus.

Fig. 7.—Marks on an isochromatic plate set behind a dark yellow screen at various focus-readings: exposure, four minutes in each case.

a. $-1\frac{1}{2}$ in. *b.* $-\frac{3}{4}$ in. *c.* visual. *d.* $+\frac{3}{4}$ in. *e.* $+1\frac{1}{2}$ in.

Fig. 8.—Three marks on an isochromatic plate kept at a fixed focus-reading: exposures with different apertures.

a. 24 inches aperture. *b.* 18 inches aperture. *c.* 12 inches aperture.

Fig. 9.—Marks made by Procyon on plate exposed at $1\frac{1}{2}$ inch within the visual focus.

	a	*b*	*c*	*d*	*e*	*f*
Exposure	8^m	4^m	1^m	1^m	4^m	8^m
	with dark yellow screen interposed.			without screen.		

On Two Distribution Maps of the Nebulæ and Clusters in Dr. Dreyer's Catalogue of 1888. By Sidney Waters.

In 1873 I had the honour to lay before the Society in two maps a graphical representation of the distribution of the nebulæ and clusters of the General Catalogue (Sir John Herschel's Catalogue of 1864). Since then the New General Catalogue (Dr. Dreyer's Catalogue) has been published; and whereas the earlier Catalogue contained the positions and descriptions of 5,079 objects, more than half as many again—*i.e.*, 7,840—are enumerated in the later one. The northern section of the Milky Way in my original maps was copied from Heis, and the southern section from Sir John Herschel's drawing; but there are now available the beautiful drawings of Dr. Boeddicker, and also those of Dr. Gould in the *Uranometria Argentina.*

It appeared to me under these circumstances that fresh maps constructed under the improved conditions would be interesting, and in the charts which I now beg to present to the Society I have laid down upon the same projection as before all the objects contained in the New General Catalogue. I have added a copy of Dr. Boeddicker's Milky Way, for which I am indebted to Mr. Wesley's excellent engraving for the northern heavens, and a copy of the Milky Way as it appears in the *Uranometria Argentina* for the southern heavens.*

The projection is that described by Sir John Herschel on p. 134 of the *Results of Astronomical Observations at the Cape of Good Hope*, and by its means equal areas in the heavens are represented by equal areas on the charts. The defect of this projection is the distortion occasioned as the Equator is approached, but for distribution maps it is practically the only projection that will satisfy the desirable condition of equal areas. The positions of all objects are laid down as accurately as possible, but the exceeding nearness of many of them to one another has made it impossible in such cases to place them in precisely their true positions,

* I have to thank Mr. Wesley for the great amount of trouble that he has taken to secure a satisfactory reproduction of the charts, and in particular for very skilfully lithographing the Milky Way upon the reduced scale.